Marine Policy 119 (2020) 104020

Contents lists available at ScienceDirect

Marine Policy

journal homepage: http://www.elsevier.com/locate/marpol

Transdisciplinary knowledge management: A key but underdeveloped skill in EBM decision-making

Diana Giebels [a,b,*], Jana Carus [c], Maike Paul [c,j], Michael Kleyer [d], Bernd Siebenhüner [a], Arne Arns [e,k], Alexander Bartholomä [f], Vanessa Carlow [g], Jürgen Jensen [e], Britta Tietjen [h], Achim Wehrmann [f], Boris Schröder [c,i]

[a] Ecological Economics, University of Oldenburg, Carl-von-Ossietzky Strasse 9-11, 26111, Oldenburg, Germany
[b] Landscape Architecture and Spatial Planning, Wageningen University, Droevendaalsesteeg 3, 6708 PB Wageningen, the Netherlands
[c] Landscape Ecology and Environmental Systems Analysis, Institute of Geoecology, Technische Universität Braunschweig, Langer Kamp 19c, 38106 Braunschweig, Germany
[d] Landscape Ecology Group, Institute of Biology and Environmental Sciences, University of Oldenburg, Carl-von-Ossietzky Strasse 9-11, 26111 Oldenburg, Germany
[e] Research Institute for Water and Environment (fwu), Dept. of Hydraulic and Coastal Engineering, University of Siegen, Civil Engineering, Paul-Bonatz-Str. 9-11, 57076 Siegen, Germany
[f] Senckenberg am Meer Wilhelmshaven, Marine Research Department, Südstrand 40, 26382 Wilhelmshaven, Germany
[g] Institute for Sustainable Urbanism, Technische Universität Braunschweig, Pockelsstrasse, 38106 Braunschweig, Germany
[h] Freie Universität Berlin, Institute of Biology Biodiversity / Theoretical Ecology, Altensteinstr. 34, 14195 Berlin, Germany
[i] Berlin-Brandenburg Institute of Advanced Biodiversity Research, Berlin, Germany
[j] Ludwig-Franzius-Institut, Leibniz Universität Hannover, Nienburger Str. 4, 30167 Hannover, Germany
[k] Faculty of Agricultural and Environmental Sciences, University of Rostock, Justus-von-Liebig-Weg 6, 18059 Rostock, Germany

A B S T R A C T

The ecosystem-based management (EBM) philosophy draws upon the principle that holistic understanding of the system to be governed needs to guide the decision-making process. However, empirical evidence is growing that knowledge integration is still a main bottleneck for EBM decision-makers. This paper argues that transdisciplinary knowledge management (TKM) is a key competence in achieving knowledge integration, while simultaneously it represents an underdeveloped research area in EBM if understood as a process of human interaction. Based on a literature review, this article summarizes and reflects upon the most recent development in the field of TKM. The paper presents a detailed definition and in-depth description of TKM as a process of human interaction and a diversity of organizational structures that effectuate TKM. Theoretically discussed premises are furthermore illuminated and evaluated by a case study that exemplifies pro-active development and implementation of TKM. Deviating case observations are presented as novel contributions to the field. They suggest new ideas and inspiration for future EBM research and policy agendas.

1. Introduction

Ecosystem-based management has become a globally acknowledged and applied approach in marine policy. It has been introduced as an alternative to traditional, sectorial decision-making, better suited to address marine systems as holistic systems and to ensure their long-term functioning, health and sustainable provision of ecosystem services [1–3]. The notion of holism refers to the need of gaining system understanding that goes further than individual species, small spatial scales, short-term perspectives and management of commodities ([4] in Ref. [5], also [6]. It aims for deep understanding of the complexity of ecosystems and their interrelatedness with human systems [7,8]. As soon as implemented in complex decision-making landscapes, holism also refers to the need of knowledge governance between multiple knowledge sources and decision-making levels, typically represented by scientists, experts, citizens or lay people and administrative-political decision-makers [9,10].

As such, the necessity to understand and govern ecosystems as holistic systems has also raised the need for a broader integration of different bodies and fields of knowledge including data governance and information synthesis [11,12]. In practice, however, the quest for knowledge integration, understood as the integration of all related forms and contents of knowledge relevant to a specific issue area such as marine ecosystems, is an on-going struggle, restricting EBM implementation [12]. Studies analysing empirical cases of EBM reveal that related challenges potentially derive from many sources. Those include

* Corresponding author. Landscape Architecture and Spatial Planning, Wageningen University, Droevendaalsesteeg 3, 6708 PB Wageningen, the Netherlands.
E-mail address: diana.giebels@wur.nl (D. Giebels).

https://doi.org/10.1016/j.marpol.2020.104020
Received 28 August 2019; Received in revised form 7 May 2020; Accepted 11 May 2020
Available online 25 June 2020

limitations of data availability and access [13,14], the problem of fragmented governance systems [15–17], and uncertainty introduced by complex problems with non-linear feedbacks, such as climate change, that challenge the possibility to design predictive models to inform decision-makers [18].

To approach such challenges many invaluable institutional governance frameworks (see for example [2] on monitoring and evaluation of spatially managed areas or [3] on nested governance structures) and decision-support tools (see for example [19] on structured decision-making or [20] on decision-making under uncertainty) have been developed to assist and facilitate EBM decision-makers in their organizational endeavour of knowledge integration. However there is one crucial challenge that has not gained much attention in EBM research so far. Based on their most recent literature review in the field, Alexander and Haward [21] conclude that there is a lack of in-depth understanding about how knowledge integration for EBM works as a process of human interaction. It is in particular important to more explicitly disentangle how the human dimension influences processes of e.g. inter-sectorial communication and data-sharing before new governance frameworks and decision-support tools are developed [21]. In essence, individual decision-makers embedded within institutions as well as wider operational contexts need to arrange common knowledge grounds for EBM to become effective. If they do not succeed in their attempts to arrange data exchanges or to develop frameworks of knowledge integration and commonly shared data interpretation, the quest for holistic understanding has failed.

This paper argues that the literature focusing on transdisciplinary knowledge management (TKM) provides helpful insights and discussions related to these challenges. By merging insights from the disciplines of knowledge management (KM) and transdisciplinarity (TD), TKM combines two important, though different disciplines, both studying how conscious generation and utilization of knowledge works in practice. It provides suggestions on how knowledge integration can be improved and most importantly how it is possible to manage knowledge integration as a group process. With a particular focus on addressing societally relevant problems and their solutions the young field of transdisciplinary research seeks not only to integrate relevant academic disciplinary knowledge [22,23], it also calls for the involvement of societal stakeholders beyond adacemia and their respective bodies of knowledge. The rapidly growing body of work in transdisciplinary research [24] developed the notion of collaborative work between researchers and non-academic experts or lay-people further. It calls for problem-focused co-operation of different scientific disciplines together with non-scientific actor groups in different stages of the research process including problem identification and definition, common research and problem-solving processes as well as interactive dissemination and implementation of results [25,26]. The transdisciplinary knowledge-production process is called upon to open up to civil society groups, holders of local lay knowledge, corporations and other stakeholders and involve them in mutual learning processes [27,28].

According to Leenhardt et al. [29] transdisciplinarity, however, has not been a very popular research strategy in natural resource management, especially marine science. Nonetheless diverse EBM scholars already acknowledged its crucial role in the process of EBM implementation. It has been argued that TD is a necessity to integrate scientific disciplines that would be needed to understand system dynamics like cross-scale linkages, emergent properties, non-linear dynamics, and uncertainty [18,29–31] and to develop comprehensive system understanding [32,33]. TKM is useful to actively engage with local actors, for example to understand the multiple causes that impact upon and cause change of our coastal systems, to develop co-produced research agendas and to identify tipping points towards ecological system shifts [32]. As a tool for spatial planning it can bridge governance levels, jurisdictions, and economic uses [34] ensuring that those who take decisions about ecosystem resources are also engaged [35,36]. It increases the relevance and practical applicability of scientific research for society and enhances the participation, collaboration and empowerment of stakeholders [37,38]. It might also be especially suitable in situations where available knowledge is of premature quality [39].

Therefore it becomes worthwhile taking a deeper look at what most recent research progress in the field has to offer and to learn about the human dimension of integrative knowledge governance. Particular aim of this paper is to identify and describe relevant discussions from state-of-the-art TKM literature, useful to understand knowledge integration within EBM contexts as processes of human interaction. Key question of this paper is to understand how TKM scholars describe TKM as a process of human interaction and through which variables TKM can be studied scientifically.

We do so by first providing a theoretical discussion of TKM based on a systematic literature review. This review dissects variables that define and impact upon TKM as a process of human interaction (section 3). In the second step we illustrate this theoretical discussion by providing in-depth case analysis of an empirical application of TKM. This application describes a start-up-phase of a science-driven EBM project, the so called RELEEZE project (section 4). Particular aim of the RELEEZE project was to organize a knowledge integration process that would result in a regionally defined and climate-sensitive EBM system perspective. To facilitate this process, a transdisciplinary knowledge integration process was set up among diverse scientific disciplines, fragmented public administrations and different types of coastal zone users. In our case analysis we describe the organizational structure of the applied TKM trajectory (section 4.2) and present the results of a process evaluation executed by all scientific project members in the aftermath of the project (section 4.3). The process evaluation was structured by the TKM variables derived from literature, to test whether and how those work in practice. As not all variables worked in practice as predicted within theory, deviating case evidence is presented as novel evidence to the field in section 5.

2. Methods

Methodologically this paper builds upon the results of a systematic literature review and a participative case study. Literature for the review has been selected via ScienceDirect (sciencedirect.com) using two different and independent search-term combinations. For all search term combinations papers have been classified regarding their relevance concerning descriptions or discussions of transdisciplinarity. For the literature selection only the most recently published articles have been included (2005–2018), as to make sure that the process definition reflects the latest state of the art. It was decided not to include additional classics of transdisciplinarity or TKM, as many of the selected papers already provided this type of discussion and subsequently draw their research design upon it.

The first search term combination used was "knowledge management" AND "transdisciplinarity", to gain an overview about scientific papers that discuss how knowledge management can be used to organize a transdisciplinary process. Secondly the terms "ecosystem based management" AND "transdisciplinarity" have been used to identify papers that discuss transdisciplinarity in the context of EBM. The first search was conducted on 6 March 2018 and revealed 48 papers of which 33 have been identified as relevant. The second search was conducted on 16 May 2018 and revealed 14 papers. All of these 14 papers have been classified as relevant and were included in the review. No duplications have been found. Table 1 provides an overview of the total numbers of papers included in this review. In addition, an overview of papers from both search selections is included as an appendix to this article.

To systematically assess the contents of identified papers a Microsoft Excel table was used to archive each article analysis. For all articles, author' names, publication year and journal name were noted. For the TKM literature it was assessed how knowledge management was defined and how the role of knowledge management was described as a human and not (only) technical process. If no definition of knowledge

Table 1
Total numbers of papers included in the literature review.

Literature search keywords	Total number of papers found	Total number of papers accessible	Total number of papers relevant and included for analysis
"knowledge management" AND "transdisciplinarity"	48	35	33
"ecosystem based management" AND "transdisciplinarity"	14	14	14
Total number of papers	62	49	47

management was provided, alternatively a short summary of the article content was made. Similarly, we provided for all EBM literature articles a content summary, the used definition of transdisciplinarity, and a discussion of how transdisciplinarity was related to EBM in terms of human process.

The participative case study was used to set up, design and evaluate a TKM process under the umbrella of the RELEEZE project. The RELEEZE project was financed by the German Federal Ministry of Education and Research (BMBF; Bundesministerium für Bildung und Forschung) within the research program 'Research for sustainable development (FONA3)'. It aimed at the development of a regional, climate sensitive EBM perspective (see section 4.1 for further detail). To generate system knowledge about the RELEEZE project area, TKM was applied to involve relevant experts and decision-makers and to facilitate the knowledge integration between experts, decision-makers and scientists. Applied TKM methods included face-to-face interviews, a digital speed-date and a joint workshop.

Relevant experts and decision-makers were identified through stakeholder analysis following the best practice guidelines of Durham et al. [40]. Accordingly all institutions that affect regional policy making in the RELEEZE research area were approached and invited for an interview. Relevant institutions included different administrative bodies representing the interests of nature protection, coastal defence, farmland use and local as well as regional land use planning. Conducted stakeholder interviews have been guided by a standardized, semi-structured questionnaire. The content of the questionnaire was structured as to understand (i) how individual respondents perceive the socio-ecological system they are operating in, (ii) how they experience or expect it to be impacted by climate change, (iii) whether and how they manage the area in an integrative way, (iv) whether they would like to pose own research questions concerning the socio-ecological system at hand, and (v) what their past experience, future expectations and wishes concerning the further participatory process are. In total 20 experts from 13 organisations have been interviewed. On average each interview took 1 h 45 min.

The results of (iv) have been fed back first to the scientific consortium members in form of a digital speed date and were in a second step transformed into a transdisciplinary research agenda together with experts and decision-makers. To facilitate the digital speed date all stakeholder questions derived from the interviews were content-transcribed and compiled in a Microsoft Excel table. Scientists were requested to indicate for each question whether or not they thought a question could be addressed by academic research. In total 57 research questions have been discussed. While 22 questions could directly be integrated in a joint research agenda, 12 questions needed to be excluded. Two reasons caused exclusion: Either the research question was already handled by a different scientific project in the region or the question was perceived by scientists as being too far away from the core focus of the project. The remaining 23 questions required further discussion. To facilitate this discussion a joint workshop was organized together with all experts, decision-makers and scientists. During this workshop all questions were discussed in detail and a final decision on which questions to include for the transdisciplinary research agenda was made. In addition, the results of (i), (ii) and (iii) were used to draw a first sketch of a transdisciplinary system map. This system map revealed an integrated conceptualization of the socio-ecological system of the project region. It comprehensively reflected scientific state-of-the-art and integrated stakeholder views on system dynamics. A simplified version of the system map is presented in section 4.2. Individual results of the stakeholder interviews and the speed date are not included to the manuscript due to word count limitations.

An ex-post reflection was organized in the aftermath of the workshop, in between October and December 2018. The project period itself lasted from June 2017 to May 2018. Inspired by Interpretative Phenomenological Analysis (IPA) [41], the ex-post reflection aimed to understand how individual participants personally perceived the process of TKM. This method was chosen as the results from the literature review revealed the necessity to conceptualize TKM as a group process. This group process is expected to be effective if all individual participants succeed to evolve throughout a common process. Hence it is important to understand how individual participants perceive the process they have been going through and whether and how their individual perceptions deviate from findings reported from other studies.

To do so all variables derived from the TKM literature review (see Table 2 for a summary) were reformulated to statements. Project participants were asked to reflect upon these statements in a written manner. They were asked to indicate whether they agree or disagree to a statement and in case they would disagree to motivate their choice. Motivated disagreements are reported as deviating TKM experience in section 4.3. In total 9 evaluations have been filled in, analysed and integrated in this section. Individual evaluation input is indicated anonymously through the capital letter R in combination with a randomly assigned number (R1, …, R9).

It was decided to only invite scientific consortium members for the

Table 2
Distilled variables from literature review defining and affecting the social process of Transdisciplinary Knowledge Management.

1.	What does a TKM process look like?	Sources
	- a group learning process	- [38,42–48]
	- requires complex human skills	- [49]
	- it is about learn how to learn	- [46,49,50]
	- non-routine type of working	- [43,48,51]
	- needs to be organized as a conscious, step-wise process	- [42,52,53] - [48,54]
	- cyclical, iterative, participative	- [37,54–56]
	- open dialogue, transparent, trusted, non-bureaucratic	- [42–44,49,54,57]
	- sequentially structured, but also emotional, creative and difficult to predict	- [46,58,59] - [46,58,59]
	- in essence self-directed, but tutored where necessary to prevent isolation of individuals or group-harming behaviour	- [37,42,60]
	- needs to be accompanied by boundary work when actors are in conflict	
	- ideally explicitly facilitated by law and organizational structure	
2.	Who is the key actor to convey TKM?	
	- not one key actor, but a group process	- [37,46,48,54,55,
	- pre-defined actor roles effectuate the group process	57,58,61,62]
	- universities are most suitable actors to initiate and facilitate TKM	- [47,50,59,63–65] - [63]
	- explicit organizational embedding e.g. through Centres of Expertise helping to effectuate the role of universities	
3.	What is the role of networks?	
	- TKM can be a tool to build up new networks	- [46,54,56]
	- TKM as a means to manage existing networks	- [48,57,60,66]
	- TKM might also use networks to manage	- [42,46,54,57]
	- networks are important organizational entities to link actors	- [37,46,53] - [54,60,63,66]
	- networks need continuous negotiation to make them work	

reflection exercise as only those have been participating throughout all phases of the project. As already mentioned above, it was not possible to organize a fully inclusive TKM process for all project members, due to the restricted timeframe available. A short summary of all findings can be found in Table 3. In case no particular elaboration or novel contribution came out of the analysis, this is indicated by the sign ✓ without text in Table 3. In case a particular elaboration could be made this is indicated by the sign ✓ followed by text. In case a deviating finding could be identified this is indicated through the use of plain text.

Table 3
Summary of the case analysis: Transdisciplinary Knowledge Management in the RELEEZE project.

TKM described in the literature	TKM perceived by participants of the RELEEZE project
1. What does a TKM process look like? - a group learning process - requiring complex human skills - it is about learning how to learn - non-routine type of working - needs to be organized as a conscious, step-wise process - cyclical, iterative, participative - open dialogue, transparent, trusted, non-bureaucratic - sequentially structured, but also emotional, creative and difficult to predict - in essence self-directed, but tutored where necessary to prevent isolation of individuals or group-harming behaviour - needs to be accompanied by boundary work when actors are in conflict - ideally explicitly facilitated by law and organizational structure	- ✓ - ✓ important to be open minded for different viewpoints, mindsets and evaluation schemes - more important to learn content-wise from each other about systems functioning and how the dynamics described by different disciplines interrelate and (potentially) effect each - ✓ being confronted with diverging societal interests; to handle ones own lack of knowledge; taking over representation and argumentation for other disciplines involved - ✓ in particular important to enable interest integration - sometimes less cyclical and iterative but more chaotic and non-linear development - ✓ trust-building activities important during the process - ✓ - willingness to cooperate and group loyalty also important drivers - tutorship also entails to propose the uncomfortable questions - ✓ system map worked well to identify boundaries and make them discussable - lack of facilitation by law or organizational structure makes voluntary commitment essential
2. Who is the key actor to convey TKM? - not one key actor, but a group process - pre-defined actor roles effectuate the group process - universities most suitable actors to initiate and facilitate TKM - explicit organizational embedding e.g. through Centres of Expertise helping to effectuate the role of universities	- ✓ - pre-defined actor roles can also harm the process by taking out it's dynamic; definition of actor roles also depends on personal character and scientific expertise needed - pre-defined actor roles in particular relevant for the integration of scientific and lay knowledge - research institutes or large governmental bodies also suited - explicit support from the organizational level of University missing
3. What is the role of networks? - TKM can be a tool to build up new networks - TKM as a means to manage existing networks - TKM might also use networks to manage - networks are important organizational entities to link actors - networks need continuous negotiation to make them work	- ✓ - also important to establish links between existing networks - ✓ - ✓ - already existing networks can also operate smoothly without negotiation; interest in participation needs to be a given to make negotiation work

3. Transdisciplinary knowledge management as a process of human interaction

In depth study of most recent progress in the discipline of TKM helped to identify variables that define and impact upon TKM as a process of human interaction. In the following sections these variables are elaborated on through resuming and synthesizing the research progress of current debate in the discipline. Section 3.1 presents a description of what TKM is if conceptualized as a human process and how it can be organized effectively. Section 3.2 resumes on specific actor roles that should be represented in a TKM process and identifies skills needed to execute these roles. Section 3.3 zooms in on the crucial role of networks as organizational entities facilitating effective TKM. An overview of all variables that have been distilled from TKM literature to structure the ex-post reflection is presented in Table 2.

3.1. *Defining transdisciplinary knowledge management*

Scholars of TKM have described the phenomenon as, in essence, a long-term group interaction and learning process. TKM works cyclical, iterative and participative and facilitates integration across a variety of actors involved [48,54]. Included actors typically stem from science or society, public or private sectors [42]. They interact through dialogue [55] aiming to deepen and extend established expertise [54]. Experts are challenged to leave their institutional comfort zones [48], while group members learn to trust and respect each other through engagement [48,54,56]. For that sake the process of interaction is transparent, including fair play rules and commitment of actors to joint goals [37].

TKM differentiates from those processes that see knowledge as a product or a service that can be delivered from producer to user. It explicitly acknowledges the need of knowledge differentiation and integration through reflection and method [26] in Ref. [45]. Transdisciplinarity implies a dynamic where the communication of knowledge becomes more relevant than its production [46,50]. It is an attempt to think about what has been unthought, developing 'what if' techniques to question the obvious and using hermeneutics and imagination to move beyond mainstreamed ways of theorizing and thinking [43]; see also [51] for an application to e-learning). As such the concept of TKM has much overlap with and belongs to the family of "sustainability science'', "mode 2" and "triple helix'' [37]; and for in-depth discussion [60], however, as discussed throughout this paper TKM forms a specialization within this field, as it is in particular concerned with knowledge integration for complex systems understanding.

3.1.1. *Effective organization of transdisciplinary knowledge management*

Many TKM scholars associated effective organization of TKM to a process separated into different phases. For each phase clear objectives need to be defined [54]. In his TKM maturity model Serna (2015) for example distinguishes in total five process phases with different objectives. In the starting phase (predisposed level) disciplinary knowledge prevails in a group and a lack of abilities to perform knowledge integration is experienced. In the second step (reaction level) the group starts to experiment with methods of knowledge integration. In this stage information starts to flow between disciplines. At the third level (evaluation level) this information flow matures. Participants get a better view on which knowledge should be integrated and how this could be done. Typically agreements are made to further facilitate integrative attempts. In the fourth step (organized level) a clear process architecture has been developed within the group, actively facilitating knowledge integration. The fifth and final step (optimized level) describes an on-going process of knowledge integration. It is characterized by continuous architectural changes to facilitate adaption to new insights and new needs of knowledge integration.

A different process view has been developed for those TKM approaches that chose to develop a modelling process. Laniak et al. [52]; for example argued that, although it is important that all actors work towards a common perspective in a TKM process, they do not necessarily need to evolve through a joint process. The final development of a system model could for example also be outsourced to specialized scientists. This type of process design has the advantage that actor constellations are more flexible and can be changed easily, for example if changing definitions of the problem demand involvement of different expertise [53]. Similar, Arnold [44] argued that in integrated natural resource modelling the knowledge management process should not look like a one-(wo)man-show, like an expert advice or like a symphony. It ideally provides a playground that makes it possible to develop and combine collaboration within an organization or cooperation with external partners to accumulate knowledge [44].

A critical view on joint process design has also been developed by Le Theule and Fronda [57]. They argued that a managerial intention to control creativity is inherent to many potential contradictions. Creation needs freedom, it is an emotional process, driven by affection, and it is difficult to predict and put into time frames (see also [49] on details of the learning process and stimulating methods for creativity). In organizational terms Le Theule and Fronda [57] use the jazz metaphor to explain how a creative process in a group can evolve without being strictly steered. They [57] emphasize that it is a more or less unplanned, very contextual happening, where skilled musicians continuously improvise being simultaneously inspired by their own feelings, colleagues, and the audience. In line with this view Gendron et al. [43] added that for TKM it is important to not only focus on the classical sources of knowledge, like objective knowledge as it is created by science, or rational knowledge as produced by philosophy; but also on the experiential knowledge as produced by art and literature [43].

The case evidence reported by Bond (et al., 2010) suggests that informal human playgrounds as suggested by Arnold [44] and Le Theule and Fronda [57] could be seen as entities that are organized in parallel to highly formalized knowledge generation processes. The development of Environmental Impact Assessments, for example, became effective by actors taking time for frequent knowledge exchange in informal meetings, organized in addition to the formal ones. Through these meetings actors had the possibility to reflect upon and change their vision about the process itself. Negotiation and leadership by a coordinator was important to make this type of knowledge integration effective [58].

To effectively organize TKM, it is also important to reckon upon the specific type of disciplines that are represented in a group learning process. Prinsloo's [67] findings suggest that individual patterns of creative thinking determine how a single actor will experience a TKM process and participate therein. His study reveals that although students of different disciplines show similarities in choosing things they like to analyse, a clear cut difference exists between students of the natural sciences versus students of engineering and music when it comes to the choice of things they dislike (see Ref. [67] on disfavour-based patterns).

Related to this finding, it is also important to note that TKM requires more complex human skills and 'higher level' competencies like the ability to create, evaluate and empathize with stakeholders [49] than traditional approaches of knowledge management do. While general knowledge management can be implemented as a routine activity by recalling and applying pre-learned content or schemes, TKM is typically applied in contexts where established knowledge claims out-date quickly. Accordingly, it becomes much more important to enhance and stimulate the so-called fluid intelligence, enabling an actor to 'learn how to learn' [49].

To effectuate mutual learning, TKM scholars suggested working formats like the experimental learning approach that combines momentum of experience, activity, and reflection (see [68,69], both cited in Ref. [45] as well as cooperative learning circles, voluntary agreements [47] and the learning organization approach [58]. The development of 'controlled vocabularies' and 'common ontologies' furthermore, can help to bridge language barriers [48]. In such settings it is especially for public administrators important to not operate too bureaucratically, as this might cause more distrust instead of trust among participating actors [37].

To let TKM evolve as a successful group process it however also is important to reckon upon potential harmful group behaviour of individual participants. Group management might therefore also urge prevention of individuals getting isolated, the exclusion of non-complying group members or be accompanied by boundary work when actors are in conflict [59] and different stakes need to be balanced [46]. In particular boundary work might be suited to support TKM, as it acknowledges and respects that actors hold different and diverging convictions. It does not try to change these convictions, but supports communication and coordination to facilitate integration (see also the discussion in Ref. [59]. To reckon upon different and diverging convictions of individual actors seems to be most essential, as it supports individual self-directedness. Self-directedness is an important asset to enable social interaction and learning [59]. For those TKM processes that entail the participation of actors that did not participate in a TKM process before, it is also important to ensure empowerment of inexperienced actors [37].

Reoccurringly, TKM scholars have also referred to the importance of external factors influencing the success of TKM. Bruckmeier and Larsen [37] mention that a change of law and the establishment of facilitating institutions would be needed to enable more stakeholder participation and to make participatory approaches fully functioning. Often it are prevailing institutional pressures like career-building paths that prevent TKM to become applied [42,60]. But also factors like perception of status and leadership style ([70] in Ref. [56] or the way data ownership is handled [48] can have significant impact. Other studies identified (i) the experience of earlier shortcomings when not managing a system in a transdisciplinary way [37], (ii) the experience of a diversity of viewpoints helping to increase insights (see Ref. [49], and (iii) the ability of actors to see impact of their efforts in an ongoing process [46] as important success factors.

3.2. Identifying key actors in transdisciplinary knowledge management

Drawing on the definition that TKM in essence is a group learning process aiming to integrate different bodies of knowledge, it is also important to clarify who should be responsible for its organization. Many of the reviewed articles explicitly addressed this topic. In particular the focal role of universities and the need to define different actor roles within a TKM process have been discussed.

3.2.1. Universities as key convenors of TKM

Many authors have argued that universities are important key convenors of TKM [47,50,59,63,64]. Scientific disciplines as Ecological Economics have, for example, explicitly defined their scientific agendas through the accomplishment of sustainability goals within society and identified TKM as an important method to achieve them [47]. By combining many different disciplines in one institution, universities potentially function as important platforms and networks to push for regional and international knowledge dependent initiatives [63]. Universities can, for example, introduce innovative management practice, technical expertise, promotion of ideals and critical thinking. They can take the lead in initiating sustainability plans or act as independent monitoring and bridging institutions [50].

Other authors have put emphasis on the educational task of universities in this matter. Knowledge management then becomes an important competence students need to learn for the acquisition, creation and critical reflection upon knowledge [65]. Case evidence suggests that for universities being a key actor to convey TKM, it is important that independently organized coordinating and bridging institutions take over the organizational process behind TKM. For example in the case of the University of Graz [63] a Regional Centre of Expertise acted as an independent coordinator, providing a network that could be used for communication and collaboration. By taking over the multi-stakeholder connection process, the centre prevented the core academic goal of the university not getting under pressure and made TKM effective.

3.2.2. Different actor roles

In the process of organizing TKM it is also important to be aware of and ascribe different roles to participating actors. Within the reviewed literature, one important actor role has been assigned to the *facilitator* who is organizing and sometimes also initiating the group learning process. The facilitator acts as a process manager [46], setting up [54] and if necessary re-evaluating [58] knowledge arrangements between participating actors. Case evidence indicates that it is important that the coordinator holds an independent position and has no vested interest in the research itself [54]. Independence is important as it enables knowledge brokerage and mediation activities when process deadlocks emerge [55]. Le Theule and Fronda [57] furthermore describe the role of the facilitator as a *translator*. He is not skilled to preach solutions, but to analyse a situation and to assist others in essential activities like reflection to help them finding a solution. A facilitator typically acts like an action researcher or consultant [57].

Different to the neutral position of the facilitator is the role of the *expert*. Experts are those actors skilled and trained for specific knowledge. It can be the scientific expert [46] or a technical specialist, trained to translate user needs into characteristics of an integrative model [48]. The empirical research of Bruckmeier and Larsen [37] shows that it depends on specific actor constellations and their perception of the actual conflict or problem at hand, how it is best to proceed in terms of how to characterize what or whom an expert is. Where scientists are working together with experts it can turn out to be useful to proceed with purely scientific methods of knowledge generation and application. However, in case conflicts emerge among participating actors, boundary spanning techniques like joint knowledge production can become more important. Within the TKM community, the added value of a system expert has also been ascribed to its external position. This position is suited to overlook a system in a holistic way, which is often not given for those being involved in and responsible to take decisions [57]. Kragt et al. [48] provide similar descriptions and definitions of actor roles within the context of integrative modelling.

Resuming TKM processes as group processes it seems also important to realize that group processes do not emerge without initiation. A knowledge generation process to evolve as a group process might urge the activities of an *animator*, someone who is breathing life into the process or acting as a *catalyst* (see Refs. [57]. These roles could be ascribed as additional activities to the facilitator, but might also be executed by separate actors. Available case evidence suggests that it is advisable to assign different actor roles to specified actors, as otherwise it can be confusing for participants to experience one person in different roles [46] and to prevent research being experienced as biased [61]. However, in case not much funding is available, Kragt et al. [48] also see the possibility for individual actors fulfilling different roles simultaneously throughout a TKM process.

Maiello et al. [55] identified a unique position of the *public administrator* throughout processes of TKM. Since typically in transdisciplinary processes many different actors are involved (e.g. citizens, politicians, scientists), it is important that one actor actively manages different knowledge insights and simultaneously assures that the outcome is still serving public interests. According to Maiello et al. [55] it is the civil servant or public administrator who should take over this role. Maiello et al. [55] developed this vision after case comparison of governance processes for urban sustainable development in which transdisciplinary approaches failed. An important factor for the lack of transdisciplinarity was that decision-makers tended to separate knowledge streams of experts and lay people.

Maiello et al.'s [55] study is the only study pointing to this dynamic, although the argumentation of Kyriazi et al. [62] also underline the need of being sensitive to this issue. In TKM, scientists typically become members of a collaborative network instead of merely being consulted for expert advice. They thus become stakeholders of the decision-making process and hence hold an interest what decisions are taken [62]. Assigning the role of public-interest keepers to participating representatives of public institutions therefore might be a means to clarify and handle delicate power structures. Equal distribution of power in turn, is essential to create mutual learning [46].

3.3. The role of networks in transdisciplinary knowledge management

The role of networks gained recurring attention in the TKM literature. They have strongly been associated to the effectiveness of systems management. As such they have been discussed from three different angles. First, scholars have argued that it is important to know and understand existing networks to make TKM effective. Secondly, existing networks might be used as a tool to manage through TKM, and thirdly, TKM might by itself be used as a tool to set up new networks.

3.3.1. Manage existing networks, use networks to manage, and build up new networks

In a TKM process the network ties between participants typically are diverse and might be electronically, organisationally, socially, and informally [60]. To make TKM work, knowledge exchange needs to be facilitated across all network members [66]. Network members need to be willing to share knowledge and to collaborate [48]. Individual network members however also need to be understood as being members of already existing networks. Such networks can have impact on the individual as well as the organizational level. On the individual level, interpersonal networks shape the identity of network members as social constructs. They can limit or on the contrary increase individual freedom of expression [57]. On the organizational level networks typically determine the whether and how of knowledge transfer and exchange [66].

Vice versa, a network - if organized in a TKM-like way - can also become a tool of management [42,54,57]. Trough the creation and improvement of space for self-organisation and learning they can provide the necessary organizational entity for knowledge integration [46]. In practice such TKM networks have for example been used to link civil society actors to formal processes of planning and management [37] and to manage geographically wide spread issues like tobacco control and pandemics [53].

Thirdly, TKM can be used to build up new networks [46], which is a necessity to establish collaboration among researchers [56]. Network creation can help to develop and increase the awareness about system knowledge and facilitate reflexive forms of learning [54]. Information and communication technologies have been identified as crucial means to effectuate this role of TKM. Particular need for improvement in this domain constitutes effective use of databases. Those are often seized ineffectively due to shortcomings like costly manual updates and expert validations needed for maintenance [71].

For all three types of network uses it seems to be important to realize that continuous negotiation is essential to make a network work. Typically, interests between heterogeneous members are not easy to combine. Communication and dissemination of knowledge is then not enough [60]. It is also important to articulate actor participation [54] and to apply knowledge brokerage, where it is needed to bridge actor cleavages [66]. Independent networking institutions can function as essential linking pins in such dynamics [63]. In addition, also the long-term management of networks urges special attention, as networks often have no permanent character, but are project related [63].

4. Results from the case analysis

4.1. Introducing the RELEEZE case

The RELEEZE case describes a science-driven transdisciplinary research project that aimed to develop a system perspective of sea level rise-induced changes in a tidal-driven coastal system. The acronym stands for 'RELease from coastal squEEZE', as one of the main aims of the project was to understand and mitigate the process of coastal squeeze. Coastal squeeze is defined as a process where rising sea levels and other factors push the coastal habitats landward, while static margins between land and sea (e.g. dikes) prevent upland migration and thus habitats become squeezed into a narrowing zone [72,73].

Geographically, the RELEEZE case was located in the German, East Frisian part of the North European Wadden Sea (EFWS). As a UNESCO World Heritage Site, the Wadden Sea represents the world's biggest tidal flat system and provides a high diversity of coastal habitats and dependent species. Its crucial role of biodiversity provision on a global scale has been internationally acknowledged [74]. The EFWS is part of the UNESCO World Heritage Site and characterized by highly dynamic sedimentary, morpho- and hydrodynamic processes (see Fig. 1).

It forms part of the southern boundary of the German Bight and is sheltered by a chain of barrier islands, bounded to the mainland by a coherent dike line. It is a mesotidal, mixed energy coastal system (e.g. Refs. [77,78], with semi-diurnal tides ranging from 2.3 m in the west to 3.0 m at its eastern margin. Overall this area is characterized by a shore parallel zonation of sediment belts [79] with grainsizes decreasing towards the mainland following the decreasing shore normal energy gradient [80–82] with coarse sand (>350 μm) in the inlet gorges and ebb-tidal deltas and very fine sand (88–125 μm) and a local mud content of >30% at the intertidal flats adjacent to the dike [83].

Coastal squeeze can induce a critical tipping point within that system. Man-made fixation of the coastline by dikes on the mainland and

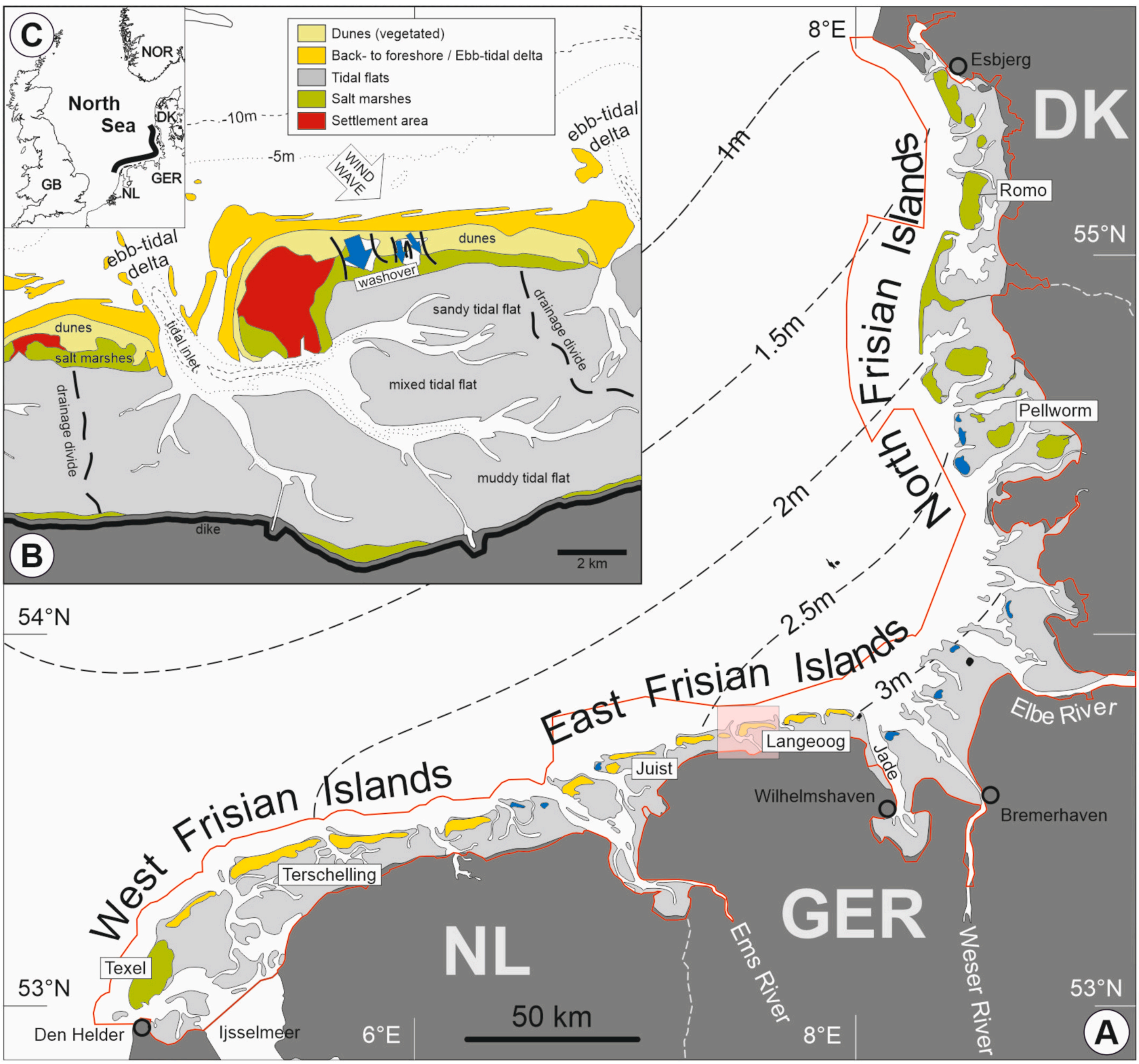

Fig. 1. (A) The RELEEZE study was situated at the East Frisian Coast which is part of the trilateral Wadden Sea National Park (red line) ranging from Den Helder in The Netherlands to Esbjerg in Denmark. Most prominent environmental factor are the tides whose range increase from 1.5 m to more than 3.5 m towards the innermost part of the German Bight. Beside the tidal flats (grey) which emerge during lowtide the chain of barrier islands (yellow), geest/marsh islands (green) and highly dynamic sand bank islands (blue) protect the coastal region from strong storm surges. (B) Principle morpho-ecological units of a barrier island and its related tidal basin in the EFWS (for lokation see pink box in (A). Modified after [75,76]. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

maintained dunes on the islands as well as accelerated sea level rise (SLR) interfere with the dynamic equilibrium of the EFWS [84] and change the hydro- and morphodynamic regimes [82,85]. As a consequence, the sediment budget will no longer be balanced, and SLR might exceed sedimentation-driven surface elevation change. The fixed system boundaries prevent natural lateral shifts in ecosystems of the EFWS. The collapse of salt marshes and dunes leading to the loss of the unique flora and fauna of the Wadden Sea might be the consequence. To create awareness and joint understanding of this problem and to eventually develop pathways for solutions a TKM process was initiated under the umbrella of the RELEEZE project, bringing together relevant scientific and societal actors and expertise.

4.2. The process of TKM in RELEEZE

TKM within the RELEEZE project was envisioned as a group learning process emerging across diverse scientific disciplines and a representation of local stakeholders. Scientific disciplines included landscape ecology and environmental systems analysis, ecological economics, political science and public administration, coastal engineering, coastal geology, marine sedimentology, ecohydrological modelling, and architecture and urban planning. Local stakeholders included representatives of agriculture, diverse coastal protection organisations, a national park administration, representatives of municipalities, the county administration as well as an overarching regional stakeholder representation board.

Communication pathways were established within the scientific consortium to provide the foundation for appreciation of the respective expertise and to enable high quality knowledge exchange. Exchange and integration of knowledge with local stakeholders was organized in parallel knowledge generation sessions. This was done as the RELEEZE project had a time frame of six month for engagement and integration of local stakeholders. This time frame was deemed too short to develop a commonly joint TKM process. Instead, face-to-face interviews have been used to speed up the process of data collection and generation on the side of the societal stakeholders (see the methods section for further detail). The so generated knowledge was integrated with scientific state-of-the-art in the form of a system map. Fig. 2 beneath shows a simplified version of this map. It can be divided into three different geographical areas, which bundle different user groups. These are the land behind the first dyke line (left side of the Figure), the Wadden area (middle of the Figure) and the barrier islands (right side of the Figure). The system components and processes that are most relevant for RELEEZE were emphasized by pictograms (e.g. agricultural use, shipping routes, bird feeding areas).

4.3. Evaluation of the RELEEZE case: elaborations and novel contributions to the field of TKM

4.3.1. TKM process perception by involved project partners

For the communication between scientists and local stakeholders it was important that an open dialogue was organized in a transparent, trusted and non-bureaucratic way (R1, R2, R3, R4, R5, R6, R7, R8). Trust however is not a given and needs to grow in processes of deliberation

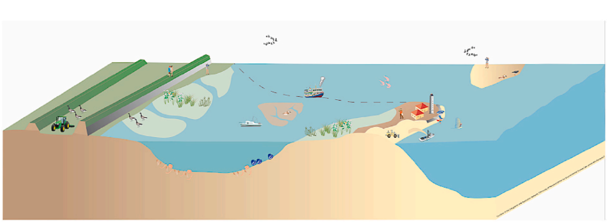

Fig. 2. Simplified version of the system map used to visualize integration of scientifc and societal knowledge.

and communication. Especially after the workshop some stakeholders felt distrust concerning a scientific bias of the project. Accordingly, an additional stakeholder meeting was organized as to discuss the experienced problems and to provide full transparency about the way the scientific consortium has been working. Establishing trust among all participants was most essential for the success of the RELEEZE project, as the TKM process itself is not facilitated by legal provisions (R1, R2, R3) or other supportive organizational structures (R5, R6, R8). Hence all participation required volunteering commitment. For some participants it was also important to accommodate the emotional and affective drivers of the knowledge creation processes (R1, R2, R4, R6, R7).

Scientific participants experienced the knowledge creation process as such being quite dynamic. Some experienced the process as cyclical, iterative and participative (R1, R2, R3, R6, R7, R8), others regarded it more as a step-by-step process (R4, R5). Cooperation and loyalty have been mentioned as important drivers to make this group process work (R5). Also continuous learning was a necessity (R1, R2, R3, R4, R5, R6, R7, R8), ranging from learning about each other's disciplines, scientific concepts and stakeholder views to learning about organizational practices. One participant perceived this dynamic as explicitly productive, as new lines of thinking could be produced and the discussion was open to new directions (R3). Accordingly, the direction of the entire process was difficult to predict (R1, R2, R3, R4, R6). Self-directedness and tutorship was mostly perceived as a necessary mechanism in the knowledge generation process (R1, R2, R4, R7), though it was not necessarily perceived as a main mechanism of learning.

Tutorship of the group was associated with the need to propose also uncomfortable questions, as those dismantle knowledge integration problems to bring the knowledge generation and integration process forward (R6). The creation of an overarching system map facilitated one of those TKM moments that emerged consciously and in a step-wise manner (R1). As such TKM was helpful to start up and structure the modelling process within the scientific consortium (R2, R5, R7). A delivery matrix was used to discuss issues like data needs and which parameters would define the model. In this matrix each scientific discipline could pose questions and demands about specific data or requests addressed to other members of the consortium.

Furthermore, TKM resulted into the identification of potential user conflicts in the project area. Although the initial project period was too short to fully explore and work on potential solutions for conflicts (R1, R3, R5), it was important to see that TKM helped to identify potential conflicts (R1, R8) and to make them discussable. In particular the description of system dynamics neutralised potentially conflicting system user perspectives. For instance, conflicting interests of e.g. grassland for grazing geese competing with agricultural interests turned out to gain a common dimension in the light of climate change, as rising sea levels might induce a substantial reduction of feeding areas for birds in the project region, irrespective of whether those are grassland, wetland or tidal flat areas. Although this description did not solve the essence of the conflict, which lies in the conflicting land use interests, it established a common ground for discussion about future developments of the area. As such TKM proved its' consensus-building potential (R1, R2, R4, R7) even though generation of new conflicts might accompany this process (R6). "Expliciting the problems, challeng[e]s and potential responses does not mean that different stakeholders will necessarily agree on solutions. They may come to very diverse evaluations, may have believes or different interests, depending on the exposure to the problem." (R8).

The scientific participants of the TKM process perceived the learning experience of 'learn-how-to-learn' as such not being different to the type of learning required for non-TKM projects (R2, R3, R4, R5, R7). Still it did require complex skills, as it is was important to be open minded for (R2, R3, R7) and curious about (R8) different viewpoints and mindsets as well as evaluation schemes (R2, R5) and to be willing to exchange knowledge (R7). Participants also found it important to learn content-wise from each other about systems functioning and how the dynamics described by different disciplines interrelate and (potentially) affect each other (R2, R3, R4, R5, R7, R8). In that dynamic, one participant observed that it was important to take "nothing for granted and [being willing] to explain one own's disciplines basics." (R1). Also it is important to accept that other disciplines work in different ways and to schedule more time for the development of definitions (R3) and to learn how a transdisciplinary project can be organized and structured (R6). A special learning curve was experienced between the natural and social scientific approaches (R5, R7). Field trips and group meetings (R7) as well as visualization techniques (R8) have been named as a most effective manner of facilitating this part of the group learning process.

The integration of different scientific disciplines for the development of the common system perspective was also experienced as a momentum of changing work routines (R5, R6, R7). For that part it was important to speak to the other disciplines involved (R8), to admit one's own lack of knowledge about parts of the system's functioning if apparent (R1) and to take over representation and argumentation for other disciplines involved when needed (R1, R7). Personal comfort zones were in particular challenged when it came to confrontation with diverging societal interests (R2) and when breaking "down the complexity of the project to one descriptor and to make sure that the common thread [of climate change] is visible in each work package."(R5).

4.3.2. Key actor perceptions of involved project partners

The RELEEZE case is representative for the statement that universities (as well as research institutes) are key actors to initiate TKM (R2, R6, R8), but that the learning process in the end is a group process, which needs to integrate regional interests as well. The specific institutional embedding of TKM therefore seems to be less relevant, as it is more about someone who is actually trying to initiate and to devote time and facilitation (R5). For the initiating organization or person it is important to know about the relevant players in the field and related difficulties, irrespective of whether based at a university, a research institute or a lager governmental authority (R3, R5, R7). As R3 put it "I think it is more about the leading person and not at which institution this takes place. I would not distinguish between universities and research institutes and […] the initiation could even arise from a ministry etc. The important thing is that the initiating institution knows the players of and difficulties at both sites".

Nevertheless RELEEZE project members experienced universities holding the advantage of being able to bring together different teams of scientists and stakeholders and provide a trustworthy environment for their interaction (R2). They can do so on in principle politically neutral ground funded by public money and not governed by economic interests (R8). As a disadvantage, universities however lack specified facilitation of TKM on the organizational level (R6, R7) what constitutes a critical restrictive factor (R2, R4). One project participant experienced the role of universities as rather neutral in that context as universities as such neither directly provide money for regional development nor have a mandate to take executive decisions (R1).

A division of actor roles has also been essential for the RELEEZE project (R3, R6, R7, R8) and was indeed applied and fulfilled in a non-rigid manner (R2, R4, R8). "Accepting the own role and accepting that others within the group have other roles helped to accept that positions and perceptions differ which caused an openmindedness and openness towards other people's contribution to the knowledge production process. This formed the basis for group learning." (R1). Pre-definition of actor roles was important to ensure that discussions would not become endless (R7). However some participants emphasized that the pre-definition of actor roles might have effectuated cooperation in a negative way, as this would take out the dynamic of the process (R5). Furthermore, it was mentioned that role definitions also depend on personal characters and need to be informed by disciplines involved in relation to what expertise a specific project urges (R8). As R8 put it "[…] even if I was a super dominant leader person, which I may be, I would anyway not be playing that role in the project, because my discipline is planning not geo ecology […]."

Most important actor roles represented in the RELEEZE project group have been the mediator, the expert and the facilitator. The role of the facilitator was mainly executed by the project leaders. The project leaders were all scientists. They initiated the project and successfully accrued governmental project funds. The expert role was executed by scientists as well as stakeholders. Scientists acted as experts within their respective disciplines (R2, R5, R6, R7). Stakeholders brought in their own interests (R2), delivered relevant local knowledge and observations, provided access to available databases and professional expertise. To let theses process of knowledge generation evolve it was crucial to assign specified responsibilities to specified project participants (R1, R3, R7).

Mediation was essential to manage occurring deadlocks in the integration between scientific disciplines and between science and societal stakeholders. For the mediation process between science and stakeholders an independent mediation expert was contracted. This person acted as discussion facilitator during the joint workshop and was briefed by the information available from the face-to-face interviews and the digital speed date. The mediator was selected as an independent facilitator of the discussion. He had no prior background or institutionalized interest in the policy domain, but was experienced with integrative processes in other sectors. However, his lack of specialized knowledge about marine EBM also implied that mediation needed to be taken over by scientific as well as societal participants whenever detailed project knowledge was needed. Mediation roles within the scientific consortium were not explicitly specified, but taken over by different scientists whenever necessary and mostly depending on the content of the occurring deadlock at hand (R4).

A classical problem occurred in the knowledge integration process between scientific and societal stakeholders. Some scientists assumed that knowledge integration would appear in a top-down fashion. This attitude hindered the knowledge integration between both types of expertise as some of the societal stakeholders expected the process to emerge in an interactive fashion. Partly, this problem was caused by unclear role definitions. Although this lack of role definitions worked well to let participants taking over and functioning in different roles throughout the project, it apparently did not work well for the process of lay knowledge integration.

4.3.3. Network perceptions of involved project partners

The RELEEZE networks were experienced as important organizational entities to make the project work and to link actors. Project participants considered that all three types of network uses that have been described in the reviewed literature also played a role throughout the RELEEZE project (R1, R2, R4, R5). Accordingly, it was important to build up new networks as to connect required expertise (R7), to manage an existing network (R8) and to use networks as a tool to manage, in particular to link individual expert groups internally (R6, R7). One respondent summarized that in particular the use of networks as a tool to manage "[m]ade tasks easier [as] communications [were] less formal and directed." (R6).

Different to the literature discussion, the RELEEZE case exemplifies that alongside the need to build up new networks, it was also important to establish links between already existing networks (R1, R2, R7). Continuous negotiation was important to make available networks work and their integration possible (R1, R2, R4, R5). Some participants perceived continuous negotiation even as a central mechanism (R1, R2), while others however experienced the network working well without a lot of negotiation (R3), smoothly running by itself (R5). However, obviously continuous negotiation was not possible with those potential network members that had no interest in participation (R6).

5. Discussion and conclusions

5.1. Discussion

Review of recent literature on TKM allowed for the identification of variables that define EBM knowledge governance as a process of human interaction. It provides valuable inputs for all those EBM scholars and practitioners having an interest to perceive, understand, study and improve EBM implementation in general and the human process of integrative EBM knowledge governance in particular.

Still it needs to be emphasized that the insights gained are limited to those experiences made by the scientific participants in the context of the RELEEZE case as well as the selected publications included to the systematic literature review. Both databases present very relevant, but also limited study material. The literature selection could be broadened by inclusion of data sources not included in ScienceDirect. The case experience could be compared across other cases. In future studies such additional data should be used to validate and eventually extend the identified number of variables.

Another limitation of this study was the time frame available to organize stakeholder integration. Within the one year overall project time only six months could be used to identify, analyse and integrate stakeholder knowledge. This time frame restricted the possibility to organize several rounds of knowledge sharing and generation. It also restricted the possibility to include scientific as well as societal project members to the ex-post reflection.

6. Conclusions

Systematic analysis of state-of-the-art literature makes clear that Transdisciplinary Knowledge Management for EBM, if understood as a process of human interaction, in essence describes a group learning process. This process implies a delicate responsibility for decision-makers as it comes along with contradictive elements. Provision of formal and transparent predictability needs to be organized in parallel to open space for emotionally driven creativity. Results of the ex-post reflection uncovered that the design of a TKM group process furthermore needs to reckon upon personnel learning patterns and preferences of individual participants. Regular monitoring of individual participants' perception of process progress might therefore be a necessity for responsible decision-makers as to fully understand how participants perceive and perform throughout a TKM process. Attention towards personal learning preferences could also be facilitated through prior talks with actors before entering an EBM TKM process.

The RELEEZE case exemplifies that traditional structured elements of a TKM process, such as the development of a system map are important tools to facilitate and effectuate the knowledge integration process. Such elements were in particular relevant to synthesize and integrate knowledge between scientific and societal experts and to mediate conflicts. Although this is not a novel finding (see for example the structured approaches developed by Ref. [19] or Kragt el al., 2013 and for a similar a argumentation), it shows that it might be necessary to perceive TKM in the context of EBM as a structured approach that might be sequenced or paralleled by more loosely coupled moments of knowledge creation. In this light, the deviating organizational approaches discussed by Serna [42] and Le Theule and Fronda [57] are not conflicting anymore, but become useable for describing and designing different parts of the same process. A structured knowledge generation process that is characterized by a clear process architecture could be comprehended by unstructured creativity sessions. This finding matches with the stakeholder triangle approach developed by Röckmann et al. [39] who argue that for the organization of EBM it is not a necessity to include all stakeholders throughout the whole decision-making process.

The research findings furthermore suggest that although universities are not necessarily the only key actors that could and should conduct TKM, it is important to highlight their special position. More than up till now experienced within EBM scholarship, scientists could act as entrepreneurs, initiating new knowledge integration processes. Outsourced facilitative support as well as process design that draws on pre-defined, though not rigidly implemented actor roles prevent loss of scientific independence in such contexts.

Strongly connected to the former arguments, is the necessity to put more focus on the role of networks. Networks have been mentioned frequently as important organizational entities facilitating TKM, in particular as being social constructs facilitating learning. Future research shall put more focus on the identification, functioning and construction of networks that use TKM to foster EBM implementation [30]. These findings comprehend the growing body of studies available on network governance and underline the importance of networks to make EBM implementation effective (see for example [86,87].

The RELEEZE case evaluation furthermore revealed that next to the conscious management of existing networks and the need to build up new networks, it is also essential to know how to manage *in-between* different, already existing networks. This finding directly connects to the recent debate on nested governance structures that have been deemed essential for EBM to become implemented effectively in particular in the European Union [3]. The RELEEZE case shows that the development of "tiered, internally consistent and mutually re-enforcing planning and decision-making systems" [3] comes along with knowledge integration across already existing, though fragmented knowledge networks. TKM is an important tool to assist this process.

Particularly relevant for TKM processes in the context of EBM finally is to realize that content-wise learning about system dynamics is crucial. The preamble 'learn-how-to-learn' is an important facilitating asset as well, but in itself not sufficient to make TKM in EBM contexts effective. Empowerment of inexperienced actors (see Ref. [37] might therefore be more essential for EBM approaches than has been discussed within the community so far. The legal or institutional support that was evaluated as an important, but missing factor in the RELEZE case, stresses that current EBM implementation heavily depends on voluntary commitment, willingness to cooperate and group loyalty.

Author contributions

DG took the lead in writing the manuscript, developed the paper structure, conducted the literature review and the evaluation exercise and wrote the first version of the case description and analysis. JC and MP provided additional content for this case description and together with AW, MK, BS@OL and BS@BS provided critical feedback to the whole manuscript. AA, AB, VC, JJ, MK, MP, BS@BS, BT, AW participated in the evaluation exercise that helped to shape the final version of the case analysis.

Acknowledgments

BS, BS, DG, JC and MP were funded by the German Ministry of Education and Research (BMBF, grants 01LC1701A/B, within the research program 'Research for sustainable development (FONA3)'.

Appendix

Overview of literature review papers [knowledge management AND transdisciplinarity]

1. Edgar Serna M.,Maturity model of transdisciplinary knowledge management, International Journal of Information Management, Volume 35, Issue 6, 2015, Pages 647–654.

2. M.S.N. Figueiredo, A.M. Pereira, Managing Knowledge - The Importance of Databases in the Scientific Production, Procedia Manufacturing, Volume 12, 2017, Pages 166–173.

3. Leila Safaei Fakhri, Fatemeh Talebzadeh, A framework for Professional citizenship education based on knowledge management

principles, Procedia - Social and Behavioral Sciences, Volume 29, 2011, Pages 1133–1142.

4. Sergio González López, J. Loreto Salvador Benítez y José María Aranda Sánchez, Social Knowledge Management from the Social Responsibility of the University for the Promotion of Sustainable Development, Procedia - Social and Behavioral Sciences, Volume 191, 2015, Pages 2112–2116.

5. Fred Luks, Bernd Siebenhüner, Transdisciplinarity for social learning? The contribution of the German socio-ecological research initiative to sustainability governance, Ecological Economics, Volume 63, 2007, Pages 418–426.

6. Tanja Tötzer, Sabine Sedlacek, Markus Knoflacher, Designing the future-A reflection of a transdisciplinary case study in Austria, Futures, Volume 43, Issue 8,2011,Pages 840–852.

7. Matthias Barth, Maik Adomβent, Daniel Fischer, Sonja Richter, Marco Rieckmann, Learning to change universities from within: a service-learning perspective on promoting sustainable consumption in higher education, Journal of Cleaner Production, Volume 62, 2014, Pages 72–81.

8. Christiaan Prinsloo, Literature as catalyst of homogenous and heterogeneous patterns of disciplinary thinking, Thinking Skills and Creativity, Volume 27, 2018, Pages 147–159.

9. Alan J. Bond, Cláudia V. Viegas, Christianne Coelho de Souza Reinisch Coelho, Paulo Maurício Selig, Informal knowledge processes: the underpinning for sustainability outcomes in EIA?, Journal of Cleaner Production, Volume 18, Issue 1, 2010, Pages 6–13.

10. Antonella Maiello, Massimo Battaglia, Tiberio Daddi, Marco Frey, Urban sustainability and knowledge: Theoretical heterogeneity and the need of a transdisciplinary framework. A tale of four towns, Futures, Volume 43, Issue 10, 2011, Pages 1164–1174.

11. Marit E. Kragt, Barbara J. Robson, Christopher J.A. Macleod, Modellers' roles in structuring integrative research projects, Environmental Modelling & Software, Volume 39, 2013, Pages 322–330.

12. Corinne Gendron, Silvester Ivanaj, Bernard Girard, Marie-Luc Arpin, Science-fiction literature as inspiration for social theorizing within sustainability research, Journal of Cleaner Production, Volume 164, 2017, Pages 1553–1562.

13. Anna Bilyatdinova, Alexandra Klimova, Revisiting Master's Program Design in Computational Science: Case of ITMO University, Procedia Computer Science, Volume 119, 2017, Pages 65–72.

14. Ruth Carbajo, Luisa F. Cabeza, Renewable energy research and technologies through responsible research and innovation looking glass: Reflexions, theoretical approaches and contemporary discourses, Applied Energy, Volume 211, 2018, Pages 792–808.

15. Thorsten R. Arnold, Procedural knowledge for integrated modelling: Towards the Modelling Playground, Environmental Modelling & Software, Volume 39, 2013, Pages 135–148.

16. Scott J. Leischow, Allan Best, William M. Trochim, Pamela I. Clark, Richard S. Gallagher, Stephen E. Marcus, Eva Matthews, Systems Thinking to Improve the Public's Health, American Journal of Preventive Medicine, Volume 35, Issue 2, Supplement, 2008, Pages S196–S203.

17. Maik Adomβent, Exploring universities' transformative potential for sustainability-bound learning in changing landscapes of knowledge communication, Journal of Cleaner Production, Volume 49, 2013, Pages 11–24.

18. José Miguel Morales Asencio, César Hueso Montoro, Joan Ernest de Pedro-Gómez, Miquel Bennasar-Veny, 1977–2017: Nursing research in Spain after 40 years in the University, Enfermería Clínica (English Edition), Volume 27, Issue 5, 2017, Pages 314–326.

19. Blanka Frydrychova Klimova, Ilona Semradova, Hermeneutic Approach and Virtual Study Environment, Procedia Technology, Volume 1, 2012, Pages 183–186.

20. Daniel Puente-Rodríguez, Erik van Slobbe, Iris A.C. Al, D.E. (Danny) Lindenbergh, Knowledge co-production in practice: Enabling environmental management systems for ports through participatory research in the Dutch Wadden Sea, Environmental Science & Policy, Volume 55, Part 3, 2016, Pages 456–466.

21. Marie Černá, Aspects of Information Management in Context with IS Selection by SME, Procedia Engineering, Volume 69, 2014, Pages 745–750.

22. M. Semih Summak, A. Elçin Gören Summak, P. Şahika Summak, Building the connection between mind, brain and educational practice; roadblocks and some prospects, Procedia - Social and Behavioral Sciences, Volume 2, Issue 2, 2010, Pages 1644–1647.

23. Mohan Raj Gurubatham, Enlivening Fluid Intelligence in Blended Active Learning within the Cognitive Literacy Value Chain Framework, Procedia - Social and Behavioral Sciences, Volume 123, 2014, Pages 238–248.

24. Sabine Sedlacek, The role of universities in fostering sustainable development at the regional level, Journal of Cleaner Production, Volume 48, 2013, Pages 74–84.

25. Ola Edvin Vie, The Need for Knowledge Integration in Renewable Energy Innovation Projects, Energy Procedia, Volume 20, 2012, Pages 364–376.

26. William Chismar, Thomas A. Horan, Bradford W. Hesse, Sue S. Feldman, Abdul R. Shaikh, Health Cyberinfrastructure for Collaborative Use-Inspired Research and Practice, American Journal of Preventive Medicine, Volume 40, Issue 5, Supplement 2, 2011, Pages S108–S114.

27. Jana Dlouhá, Laura Macháčková-Henderson, Jiří Dlouhý, Learning networks with involvement of higher education institutions, Journal of Cleaner Production, Volume 49, 2013, Pages 95–104.

28. Patricia L. Mabry, Deborah H. Olster, Glen D. Morgan, David B. Abrams, Interdisciplinarity and Systems Science to Improve Population Health: A View from the NIH Office of Behavioral and Social Sciences Research, American Journal of Preventive Medicine, Volume 35, Issue 2, Supplement, 2008, Pages S211–S224.

29. Guillermo Cortes Robles, Stéphane Negny, Jean Marc Le Lann, Case-based reasoning and TRIZ: A coupling for innovative conception in Chemical Engineering, Chemical Engineering and Processing: Process Intensification, Volume 48, Issue 1, 2009, Pages 239–249.

30. Sam Cole, The Zeitgeist of Futures?, Futures, Volume 40, Issue 10, 2008, Pages 894–902.

31. Guillermo Cortes Robles, Stéphane Negny, Jean Marc Le Lann, Case-based reasoning and TRIZ: A coupling for innovative conception in Chemical Engineering, Chemical Engineering and Processing: Process Intensification, Volume 48, Issue 1, 2009, Pages 239–249.

32. Gerard F. Laniak, Gabriel Olchin, Jonathan Goodall, Alexey Voinov, Mary Hill, Pierre Glynn, Gene Whelan, Gary Geller, Nigel Quinn, Michiel Blind, Scott Peckham, Sim Reaney, Noha Gaber, Robert Kennedy, Andrew Hughes, Integrated environmental modelling: A vision and roadmap for the future, Environmental Modelling & Software, Volume 39, 2013, Pages 3–23.

33. William R. Sheate, Maria Rosário Partidário, Strategic approaches and assessment techniques - Potential for knowledge brokerage towards sustainability, Environmental Impact Assessment Review, Volume 30, Issue 4, 2010, Pages 278–288.

34. Karl Bruckmeier, Christina Höj Larsen, Swedish coastal fisheries–From conflict mitigation to participatory management, Marine Policy, Volume 32, Issue 2, 2008, Pages 201–211.

35. Marie Astrid Le Theule, Yannick Fronda, The organization in tension between creation and rationalization: facing management views to artistic and scientific creators, Critical Perspectives on Accounting, Volume 16, Issue 6, 2005, Pages 749–786.

Overview of literature review papers [ecosystem based management AND transdisciplinarity]

1. Christine Röckmann, Judith van Leeuwen, David Goldsborough, Marloes Kraan, Gerjan Piet, The interaction triangle as a tool for understanding stakeholder interactions in marine ecosystem based management, Marine Policy, Volume 52, 2015, Pages 155–162.

2. Elena Gissi, Juan Luis Suarez de Vivero, Exploring marine spatial

planning education: Challenges in structuring transdisciplinarity, Marine Policy, Volume 74, 2016, Pages 43–57.

3. Pierre Leenhardt, Lida Teneva, Stuart Kininmonth, Emily Darling, Sarah Cooley, Joachim Claudet, Challenges, insights and perspectives associated with using social-ecological science for marine conservation, Ocean & Coastal Management, Volume 115, 2015, Pages 49–60.

4. Andrew E.F. Allison, Mark E. Dickson, Karen T. Fisher, Simon F. Thrush, Dilemmas of modelling and decision-making in environmental research, Environmental Modelling & Software, Volume 99, 2018, Pages 147–155.

5. Ebba Brink, Theodor Aalders, Dóra Ádám, Robert Feller, Yuki Henselek, Alexander Hoffmann, Karin Ibe, Aude Matthey-Doret, Moritz Meyer, N. Lucian Negrut, Anna-Lena Rau, Bente Riewerts, Lukas von Schuckmann, Sara Törnros, Henrik von Wehrden, David J. Abson, Christine Wamsler, Cascades of green: A review of ecosystem-based adaptation in urban areas, Global Environmental Change, Volume 36, 2016, Pages 111–123.

6. Richard Le Heron, Nick Lewis, Karen Fisher, Simon Thrush, Carolyn Lundquist, Judi Hewitt, Joanne Ellis, Non-sectarian scenario experiments in socio-ecological knowledge building for multi-use marine environments: Insights from New Zealand's Marine Futures project, Marine Policy, Volume 67, 2016, Pages 10–21.

7. Vivian M. Nguyen, Abigail J. Lynch, Nathan Young, Ian G. Cowx, T. Douglas Beard, William W. Taylor, Steven J. Cooke, To manage inland fisheries is to manage at the social-ecological watershed scale, Journal of Environmental Management, Volume 181, 2016, Pages 312–325.

8. Ana K. Spalding, Kelly Biedenweg, Socializing the coast: Engaging the social science of tropical coastal research, Estuarine, Coastal and Shelf Science, Volume 187, 2017, Pages 1–8.

9. S. Ranger, J.O. Kenter, R. Bryce, G. Cumming, T. Dapling, E. Lawes, P.B. Richardson, Forming shared values in conservation management: An interpretive-deliberative-emocratic approach to including community voices, Ecosystem Services, Volume 21, Part B, 2016, Pages 344–357.

10. Zacharoula Kyriazi, Frank Maes, Marijn Rabaut, Magda Vincx, Steven Degraer, The integration of nature conservation into the marine spatial planning process, Marine Policy, Volume 38, 2013, Pages 133–139.

11. Christopher M. Raymond, Jasper O. Kenter, Tobias Plieninger, Nancy J. Turner, Karen A. Alexander, Comparing instrumental and deliberative paradigms underpinning the assessment of social values for cultural ecosystem services, Ecological Economics, Volume 107, 2014, Pages 145–156.

12. Jesse G. Hastings, Rebecca L. Gruby, Leila S. Sievanen, Science-based coastal management in Fiji: Two case studies from the NGO sector, Marine Policy, Volume 36, Issue 4, 2012, Pages 907–914.

13. Alice Newton, Tim J.B. Carruthers, John Icely, The coastal syndromes and hotspots on the coast, Estuarine, Coastal and Shelf Science, Volume 96, 2012, Pages 39–47.

14. Karl Bruckmeier, Christina Höj Larsen, Swedish coastal fisheries–From conflict mitigation to participatory management, Marine Policy, Volume 32, Issue 2, 2008, Pages 201–211.

References

[1] H.M. Leslie, K.L. McLeod, Confronting the challenges of implementing marine ecosystem-based management, Front. Ecol. Environ. 5 (10) (2007) 540–548.
[2] V. Stelzenmüller, et al., Monitoring and evaluation of spatially managed areas: a generic framework for implementation of ecosystem based marine management and its application, Mar. Pol. (2012), https://doi.org/10.1016/j.marpol.2012.04.012.
[3] J. Raakjaer, J. van Leeuwen, J. van Tatenhove, M. Hadjimichael, Ecosystem-based marine management in European regional seas calls for nested governance structures and coordination – a policy brief, Mar. Pol. 50 (2014) 373–381.
[4] J Lubchenco, The scientific basis of ecosystem management: framing the context, language, and goals, in: J Zinn, ML Corn (Eds.), Ecosystem Management: Status and Potential. 103rd Congress, 2nd Session, Committee Print. US Government Printing Office, Superintendent of Documents, Washington, DC, 1994, pp. 33–39.
[5] K. Sherman, A.M. Duda, An ecosystem approach to global assessment and management of coastal waters, Mar. Ecol. Prog. Ser. 190 (1999) 271–287.
[6] S.B. Olsen, D. Nickerson, The governance of coastal ecosystems at the regional scale: an analysis of the strategies and outcomes of long-term pro- grams. Coastal Management Report #2243, University of Rhode Island, Coastal Resources Center, Narragansett, RI, 2003.
[7] K.L. McLeod, J. Lubchenco, S.R. Palumbi, A.A. Rosenberg, Scientific consensus statement on marine ecosystem-based management, Signed by 217 academic scientists and policy experts with relevant expertise and published by the Communication Partnership for Science and the Sea at, http://compassonline.org/?q=EBM, 2005.
[8] UNEP, Taking Steps toward Marine and Coastal Ecosystem-Based Management – an Introductory Guide, 2011.
[9] D. Giebels, A. van Buuren, J. Edelenbos, Ecosystem-based management in the Wadden Sea: principles for the governance of knowledge, J. Sea Res. 82 (2013) 176–187.
[10] N.J.I. Rodriguez, A comparative analysis of holistic marine management regimes and ecosystem approach in marine spatial planning in developed countries, Ocean Coast Manag. 137 (2017) 185–197.
[11] R. Curtin, R. Prellezo, Understanding marine ecosystem based management: a literature review, Mar. Pol. 34 (2010) 821–830.
[12] H. Tallis, P.S. Levin, M. Ruckelshaus, S.E. Lester, K.L. McLeod, D.L. Fluharty, B. S. Halpern, The many faces of ecosystem-based management: making the process work today in real places, Mar. Pol. 34 (2010) 340–348.
[13] P.M. Gilliland, D. Laffoley, Key elements and steps in the process of developing ecosystem-based marine spatial planning, Mar. Pol. 32 (5) (2008) 787–796, https://doi.org/10.1016/j.marpol.2008.03.022. ISSN 0308-597X.
[14] C. Caldow, M.E. Monaco, S.J. Pittman, M.S. Kendall, T.L. Goedeke, C. Menza, B. P. Kinlan, B.M. Costa, Biogeographic assessments: a framework for information synthesis in marine spatial planning, Mar. Pol. 51 (2015) 423–432.
[15] M. Ruckelshaus, T. Klinger, N. Knowlton, D.P. DeMaster, Marine ecosystem-based management in practice: scientific and governance challenges, Bioscience 58 (1) (2008) 53–63.
[16] Katsanevakis, et al., Ecosystem-based marine spatial management: review of concepts, policies, tools and critical issues, Ocean Coast Manag. 54 (2011) 807–820.
[17] J. van Leeuwen, J. Raakjaer, L. van Hoof, J. van Tatenhove, R. Long, K. Ounanian, Implementing the Marine Strategy Framework Directive: a policy perspective on regulatory, institutional and stakeholder impediments to effective implementation, Mar. Pol. 50 (2014) 325–330. Part B.
[18] A.E.F. Allison, M.E. Dickson, K.T. Fisher, S.F. Thrush, Dilemmas of modelling and decision-making in environmental research 99, Environmental Modelling & Software, 2018, pp. 147–155.
[19] M.J. Espinosa-Romero, K.M.A. Chan, T. McDaniels, D.M. Dalmer, Structuring decision-making for ecosystem-based management, Marine Policy 35 (5) (2011) 575–583.
[20] A.M. Knights, F. Culhane, S.S. Hussain, K.N. Papadopoulou, G.J. Piet, J. Raakjaer, S.I. Rogers, L.A. Robinson, A step-wise process of decision-making under uncertainty when implementing environmental policy, Environ. Sci. Pol. 39 (2014) 56–64.
[21] K.A. Alexander, M. Haward, The human side of marine ecosystem-based management (EBM): 'Sectoral interplay' as a challenge to implementing EBM, 2019.
[22] G. Hirsch Hadorn, H. Hoffmann-Riem, S. Biber-Klemm, W. Grossenbacher-Mansuy, D. Joye, C. Pohl, U. Wiesmann, E. Zemp, Handbook of Transdisciplinary Research, Springer, Heidelberg, Berlin, Dordrecht, 2008.
[23] J.H. Bernstein, Transdisciplinarity: a review of its origins, development, and current issues, J. Res. Pract. 11 (2015) 1–20.
[24] P. Brandt, A. Ernst, F. Gralla, C. Luederitz, D.J. Lang, J. Newig, F. Reinert, D. J. Abson, H. von Wehrden, A review of transdisciplinary research in sustainability science, Ecol. Econ. 92 (2013) 1–15.
[25] T. Jahn, M. Bergmann, F. Keil, Transdisciplinarity: between mainstreaming and marginalization, Ecol. Econ. 79 (2012) 1–10.
[26] D.J. Lang, A. Wiek, M. Bergmann, M. Stauffacher, P. Martens, P. Mol, M. Swilling, C.J. Thomas, Transdisciplinary research in sustainability science: practice, principles, and challenges, Sustain. Sci. 7 (2012) 25–43.
[27] C. Pohl, What is progress in transdisciplinary research? Futures 43 (2011) 618–628.
[28] A. Wiek, Challenges of transdisciplinary research as interactive knowledge generation - experiences from transdisciplinary case study research, GAIA - Ecol. Perspect. Sci. Soc. 16 (2007) 52–57.
[29] P. Leenhardt, L. Teneva, S. Kininmonth, E. Darling, S. Cooley, J. Claudet, Challenges, insights and perspectives associated with using social-ecological science for marine conservation, Ocean Coast Manag. 115 (2015) 49–60.
[30] J.G. Hastings, R.L. Gruby, L.S. Sievanen, Science-based coastal management in Fiji: two case studies from the NGO sector, Mar. Pol. 36 (4) (2012) 907–914.
[31] A.K. Spalding, K. Biedenweg, Socializing the coast: Engaging the social science of tropical coastal research, Estuarine, Coastal and Shelf Sci. 187 (2017) 1–8.
[32] A. Newton, T.J.B. Carruthers, J. Icely, The coastal syndromes and hotspots on the coast, Estuarine, Coastal and Shelf Sci. 96 (2012) 39–47.
[33] V.M. Nguyen, A.J. Lynch, N. Young, I.G. Cowx, T.D. Beard, W.W. Taylor, S. J. Cooke, To manage inland fisheries is to manage at the social-ecological watershed scale, J. Environ. Manag. 181 (2016) 312–325.
[34] E. Gissi, J.L. Suarez de Vivero, Exploring marine spatial planning education: challenges in structuring transdisciplinarity, Mar. Pol. 74 (2016) 43–57.

[35] S. Ranger, J.O. Kenter, R. Bryce, G. Cumming, T. Dapling, E. Lawes, P. B. Richardson, Forming shared values in conservation management: an interpretive-deliberative-democratic approach to including community voices, Ecosyst. Serv. 21 (2016) 344–357. Part B.
[36] R. Le Heron, N. Lewis, K. Fisher, S. Thrush, C. Lundquist, J. Hewitt, J. Ellis, Non-sectarian scenario experiments in socio-ecological knowledge building for multi-use marine environments: insights from New Zealand's Marine Futures project, Mar. Pol. 67 (2016) 10–21.
[37] K. Bruckmeier, C.H. Larsen, Swedish coastal fisheries – from conflict mitigation to participatory management, Mar. Pol. 32 (2) (2008) 201–211.
[38] E. Brink, T. Aalders, D. Ádám, R. Feller, Y. Henselek, A. Hoffmann, K. Ibe, A. Matthey-Doret, M. Meyer, N.L. Negrut, A.-L. Rau, B. Riewerts, L. von Schuckmann, S. Törnros, H. von Wehrden, D.J. Abson, C. Wamsler, Cascades of green: a review of ecosystem-based adaptation in urban areas, Global Environ. Change 36 (2016) 111–123.
[39] C. Röckmann, J. van Leeuwen, D. Goldsborough, M. Kraan, G. Piet, The interaction triangle as a tool for understanding stakeholder interactions in marine ecosystem based management, Mar. Pol. 52 (2015) 155–162.
[40] E. Durham, H. Baker, M. Smith, E. Moore, V. Morgan, The BiodivERsA Stakeholder Engagement Handbook, 2014. Paris.
[41] J.A. Smith, P. Shinebourne, Interpretative phenomenological analysis, in: H. Cooper, P.M. Camic, D.L. Long, A.T. Panter, D. Rindskopf, K.J. Sher (Eds.), APA Handbooks in Psychology®, APA Handbook of Research Methods in psychology Research Designs: Quantitative, Qualitative, Neuropsychological, and Biological, vol. 2, American Psychological Association, 2012, pp. 73–82, https://doi.org/10.1037/13620-005.
[42] E.M. Serna, Maturity model of transdisciplinary knowledge management, Int. J. Inf. Manag. 35 (6) (2015) 647–654.
[43] C. Gendron, S. Ivanaj, B. Girard, M.-L. Arpin, Science-fiction literature as inspiration for social theorizing within sustainability research, J. Clean. Prod. 164 (2017) 1553–1562.
[44] T.R. Arnold, Procedural knowledge for integrated modelling: towards the Modelling Playground 39, Environmental Modelling & Software, 2013, pp. 135–148.
[45] M. Barth, M. Adomβent, D. Fischer, S. Richter, M. Rieckmann, Learning to change universities from within: a service-learning perspective on promoting sustainable consumption in higher education, J. Clean. Prod. 62 (2014) 72–81.
[46] T. Tötzer, S. Sedlacek, M. Knoflacher, Designing the future-A reflection of a transdisciplinary case study in Austria, Futures 43 (8) (2011) 840–852.
[47] F. Luks, B. Siebenhüner, Transdisciplinarity for social learning? The contribution of the German socio-ecological research initiative to sustainability governance, Ecol. Econ. 63 (2007) 418–426.
[48] M.E. Kragt, B.J. Robson, C.J.A. Macleod, Modellers' roles in structuring integrative research projects, Environ. Model. Software 39 (2013) 322–330, 1364–8152.
[49] M.R. Gurubatham, Enlivening fluid intelligence in blended active learning within the cognitive literacy value chain framework, Procedia - Soc. Behav. Sci. 123 (2014) 238–248.
[50] M. Adomβent, Exploring universities' transformative potential for sustainability-bound learning in changing landscapes of knowledge communication, J. Clean. Prod. 49 (2013) 11–24.
[51] B.F. Klimova, I. Semradova, Hermeneutic approach and virtual study environment, Procedia Technol. 1 (2012) 183–186.
[52] G.F. Laniak, G. Olchin, J. Goodall, A. Voinov, M. Hill, P. Glynn, G. Whelan, G. Geller, N. Quinn, M. Blind, S. Peckham, S. Reaney, N. Gaber, R. Kennedy, A. Hughes, Integrated environmental modeling: a vision and roadmap for the future 39, Environmental Modelling & Software, 2013, pp. 3–23.
[53] S.J. Leischow, A. Best, W.M. Trochim, P.I. Clark, R.S. Gallagher, S.E. Marcus, E. Matthews, Systems thinking to improve the Public's health, Am. J. Prev. Med. 35 (2) (2008). Supplement, Pages S196-S203.
[54] D. Puente-Rodríguez, E. van Slobbe, I.A.C. Al, D.E. Lindenbergh, Knowledge co-production in practice: enabling environmental management systems for ports through participatory research in the Dutch Wadden Sea, Environ. Sci. Pol. 55 (3) (2016) 456–466.
[55] A. Maiello, M. Battaglia, T. Daddi, M. Frey, Urban sustainability and knowledge: theoretical heterogeneity and the need of a transdisciplinary framework, A tale of four towns, Futures 43 (10) (2011) 1164–1174.
[56] J.M. Morales Asencio, C. Hueso Montoro, J. Ernest de Pedro-Gómez, M. Bennasar-Veny, 1977-2017: Nursing Research in Spain after 40 Years in the University, Enfermería Clínica (English Edition) ume 27 (5) (2017) 314–326.
[57] M.A. Le Theule, Y. Fronda, The organization in tension between creation and rationalization: facing management views to artistic and scientific creators, Crit. Perspect. Account. 16 (6) (2005) 749–786.
[58] A.J. Bond, C.V. Viegas, C. Coelho de Souza Reinisch Coelho, P.M. Selig, Informal knowledge processes: the underpinning for sustainability outcomes in EIA? J. Clean. Prod. 18 (1) (2010) 6–13.
[59] J. Dlouhá, L. Macháčková-Henderson, J. Dlouhý, Learning networks with involvement of higher education institutions, J. Clean. Prod. 49 (2013) 95–104.
[60] O.E. Vie, The need for knowledge integration in renewable energy innovation projects, Energy Procedia 20 (2012) 364–376.
[61] C.M. Raymond, J.O. Kenter, T. Plieninger, N.J. Turner, K.A. Alexander, Comparing instrumental and deliberative paradigms underpinning the assessment of social values for cultural ecosystem services, Ecol. Econ. 107 (2014) 145–156.
[62] Z. Kyriazi, F. Maes, M. Rabaut, M. Vincx, S. Degraer, The integration of nature conservation into the marine spatial planning process, Mar. Pol. 38 (2013) 133–139.
[63] S. Sedlacek, The role of universities in fostering sustainable development at the regional level, J. Clean. Prod. 48 (2013) 74–84.
[64] S. González López, J. Loreto Salvador Benítez, J.M. Aranda Sánchez, Social knowledge management from the social responsibility of the university for the promotion of sustainable development 191, Procedia - Social and Behavioral Sciences, 2015, pp. 2112–2116.
[65] L. Safaei Fakhri, F. Talebzadeh, A framework for Professional citizenship education based on knowledge management principles, Procedia - Soc. Behav. Sci. 29 (2011) 1133–1142.
[66] W.R. Sheate, M.R. Partidário, Strategic approaches and assessment techniques - potential for knowledge brokerage towards sustainability, Environ. Impact Assess. Rev. 30 (4) (2010) 278–288.
[67] C. Prinsloo, Literature as catalyst of homogenous and heterogeneous patterns of disciplinary thinking, Think. Skills Creativ. ISSN: 1871-1871 27 (2018) 147–159.
[68] D.A. Schön, The Reflective Practitioner. How Professionals Think in Action, Reprinted. Ashgate, Aldershot, 2009.
[69] D.A. Kolb, Learning styles and learning spaces: enhancing experiential learning in higher education, Academy of Management Learning & Education 4 (2005) 193–212.
[70] D. Stokols, S. Misra, RP. Moser, KL. Hall, BK. Taylor, The ecology of team science: understanding contextual influences on transdisciplinary collaboration, Am. J. Prev. Med. 35 (2008) S96–115.
[71] M.S.N. Figueiredo, A.M. Pereira, Managing knowledge - the importance of databases in the scientific production, Procedia Manuf. 12 (2017) 166–173.
[72] J.P. Doody, Coastal squeeze an historical perspective, J. Coast Conserv. 10 (2004) 129–138.
[73] N. Pontee, Defining coastal squeeze: a discussion, Ocean Coast Manag. 84 (2013) 204–207.
[74] WSWH, Website of the Wadden Sea World Heritage, Last Visited on 06.05.2020, 2020. https://www.waddensea-worldheritage.org.
[75] A. Wehrmann, M. Schwartz, N. Hecker, G. Liebezeit, Initial barrier island evolution (Kachelotplate, Central Wadden Sea): sediment-vegetation interaction, in: U. Hellwig, M. Stock (Eds.), Dynamic Islands in the Wadden Sea. – Wadden Sea Ecosystem vol. 33, 2014, pp. 17–27.
[76] A. Wehrmann, Wadden Sea, in: J. Harff, M. Meschede, S. Petersen, J. Thiede (Eds.), Encyclopedia of Marine Geosciences, Springer, 2016.
[77] R.A. Davis, D.M. FitzGerald, Beaches and Coasts, Blackwell Publ, Malden, Mass., 2004, p. 419.
[78] M.O. Hayes, Barrier island morphology as a function of tidal and wave regime, in: S.P. Leatherman (Ed.), Coastal Slumping on Barrier Islands, Academic Press, New York, 1979, pp. 1–27.
[79] B.W. Flemming, K. Ziegler, High-resolution grain size distribution patterns and textural trends in the backbarrier environment of Spiekeroog island (Southern North Sea), Senckenberiana maritima 26 (1996) 1–24.
[80] E.E. Antia, B.W. Flemming, G. Wefer, Sedimentary facies associations of the shoreface-connected ridge systems in the German Bight, southern North Sea, Dtsch. Hydrogr. Z. 46 (3) (1994) 229–244, https://doi.org/10.1007/BF02226951.
[81] G. Hertweck, A. Wehrmann, G. Liebezeit, M. Steffens, Ichnofabric zonation in modern tidal flats: palaeoenvironmental and palaeotrophic implications, Senckenberiana maritima 35 (2) (2005) 189–201.
[82] S. Mai, A. Bartholomä, The missing mud flats of the Wadden Sea: a reconstruction of sediments and accomodation space lost in the wake of land reclamation, in: B. W. Flemming, M.T. Delafontaine, G. Liebezeit (Eds.), Muddy Coast Dynamics and Resource Management, 1, Elsevier, Amsterdam, 2000, pp. 257–272.
[83] B.W. Flemming, N. Nyandwi, Land reclamation as a cause of fine-grained sediment depletion in backbarrier tidal flats (Southern North Sea), Neth. J. Aquat. Ecol. 28 (3–4) (1994) 299–307, https://doi.org/10.1007/BF02334198.
[84] A.P. Oost, P. Hoekstra, A. Wiersma, B.W. Flemming, E.J. Lammerts, M. Pejrup, J. Hofstede, B. van der Valk, P. Kiden, J. Bartholdy, M.W. van der Berg, P.C. Vos, S. de Vries, Z.B. Wang, Barrier island management: lessons from the past and directions for the future, Ocean Coast Manag. 68 (2012) 18–38, https://doi.org/10.1016/j.ocecoaman.2012.07.010.
[85] P. Cheng, R.E. Wilson, Modeling sediment suspensions in an idealized tidal embayment: importance of tidal asymmetry and settling lag, ESCO 31 (5) (2008) 828–842, https://doi.org/10.1007/s12237-008-9081-4.
[86] T. Smythe, R. Thompson, C. Garcia-Quijano, The inner workings of collaboration in marine ecosystem-based management: a social network analysis approach, Mar. Pol. 50 (2014) 117–125.
[87] Ö. Bodin, A. Sandström, B. Crona, Collaborative networks for effective ecosystem-based management: a set of working hypotheses, Pol. Stud. J. 45 (Issue 2) (2017), https://doi.org/10.1111/psj.12146.